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Species Profile: Wood Stork (*Mycteria americana*) on Military Installations in the Southeastern United States

by Wilma A. Mitchell

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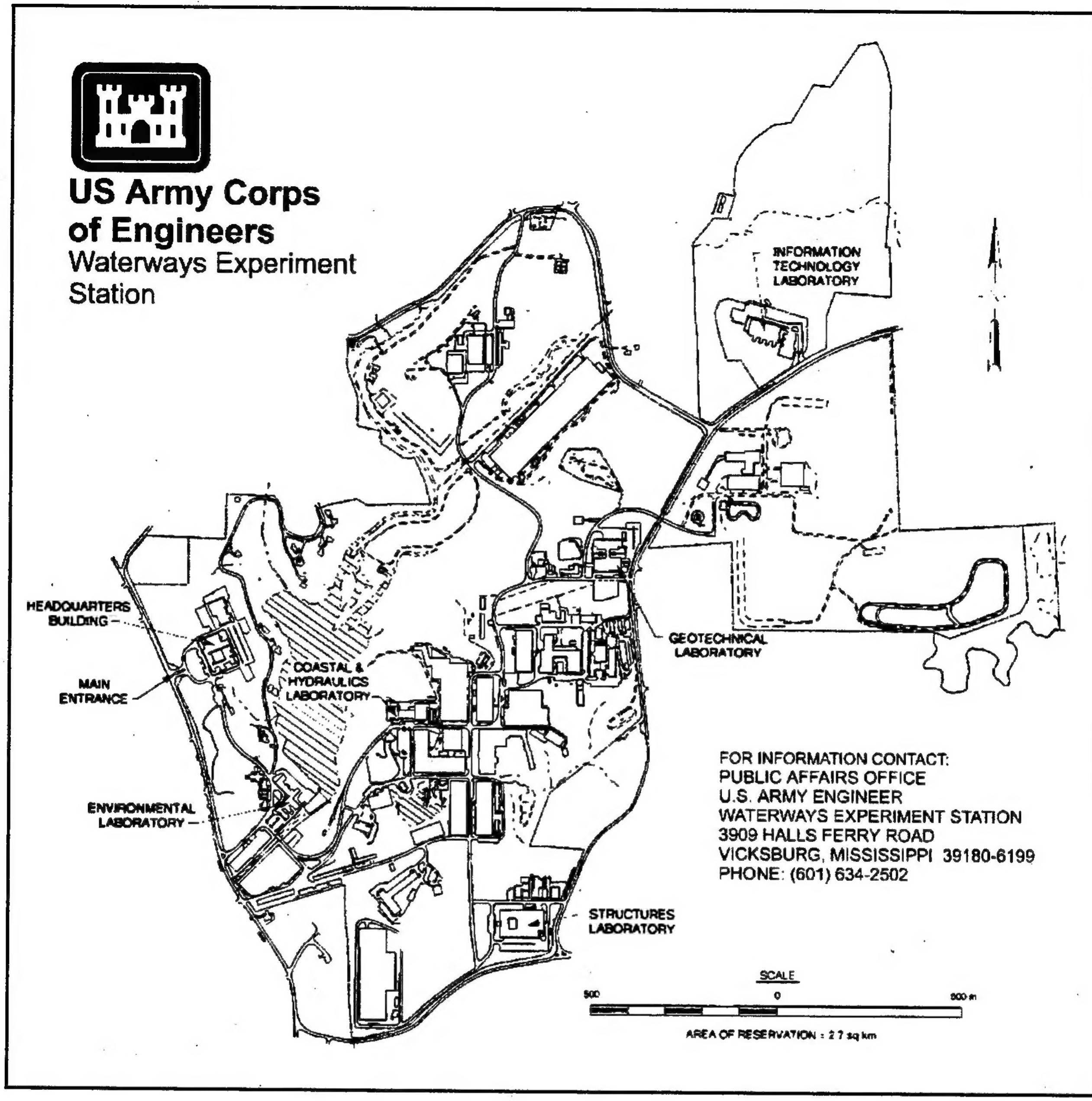

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Preface

The work described in this report was authorized by the Strategic Environmental Research and Development Program (SERDP), Washington, DC. The work was performed under the SERDP study entitled "Regional Guidelines for Managing Threatened and Endangered Species Habitats." Mr. Brad Smith was Executive Director, SERDP.

This report was prepared by Dr. Wilma A. Mitchell, Natural Resources Division (NRD), Environmental Laboratory (EL), U.S. Army Engineer Waterways Experiment Station (WES), Vicksburg, MS, a complex of five laboratories of the U.S. Army Engineer Engineer Research and Development Center (ERDC). Mr. Chester O. Martin, EL, and Ms. Ann-Marie Trame, Land Management Laboratory, U.S. Army Construction Engineering Research Laboratories (CERL), ERDC, Champaign, IL, were Principal Investigators for the regional guidelines work unit. Dr. Richard A. Fischer, EL, managed and coordinated preparation of species profiles for this study. Report review was provided by Mr. Larry Bryan, Savannah River Ecology Laboratory, Aiken, SC; Mr. John Robinette, U.S. Fish and Wildlife Service, Savannah, GA; and Mr. Paul Schoenfeld, King's Bay Naval Station, King's Bay, GA. Technical review was provided by Mr. Martin and Mr. Michael Guilfoyle, EL.

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Species Profile: Wood Stork
(Mycteria americana)

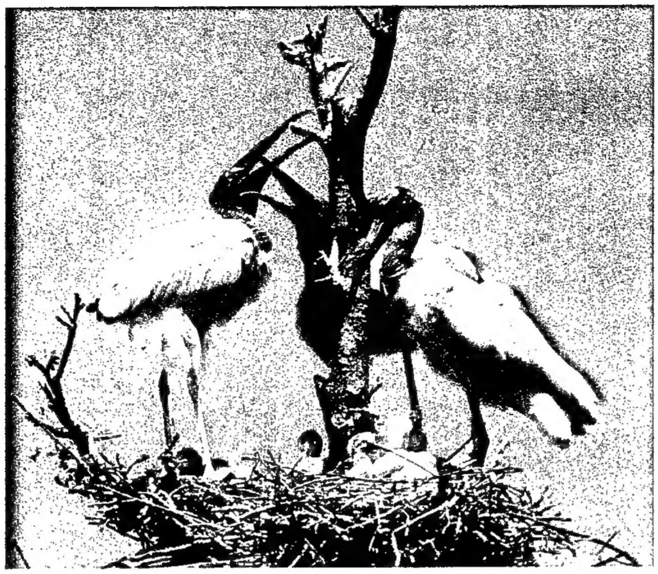

Photo by Jim Barber

Taxonomy

Class	Aves
Order	Ciconiiformes
Family	Ciconiidae
Genus/species	*Mycteria americana*
Other Common Names	Wood ibis, ironhead, flinthead

Description

The wood stork is a very large, long-legged wading bird approximately 1.3 m (4.3 ft) tall (U.S. Fish and Wildlife Service (USFWS) 1999). Its body length (tip of bill to end of tail) is about 1 m (3.3 ft), and its wingspan is 1.7 m (5.6 ft) (Peterson 1980). The plumage is white except for the iridescent black primaries and secondaries and a short black tail. During the breeding season a band of pale salmon-pink appears down the white underwing coverts (Kahl 1972). The adult has an unfeathered head and neck covered with grayish-tan crusty skin broken into small scale-like plates. A band of smooth, black skin about 50 mm (2 in.) wide lies across the top of the head behind the eyes. The forehead is a smooth, tan frontal plate; the large, decurved bill is thick and dusky or reddish-brown with blotches and streaks of black. The iris is dark brown, the legs are black, and the toes are flesh pink. Sexes are similar, but the male is slightly larger and has a longer, heavier bill. The adult wood stork holds its neck and legs fully extended in flight.

The immature wood stork is similar to the adult but has a grayish-brown feathered head and neck and yellow bill (National Geographic Society 1983; Stokes and Stokes 1996). Wood storks require several years to reach maturity (Kahl 1964). Storks still show some immature plumage at 3 years but have acquired full adult plumage by 4 years of age (USFWS 1996).

Similar Species

The American white pelican (*Pelecanus erythrorhynchos*) has a wing pattern (white with black primaries and outer secondaries) similar to that of the wood stork and soars on thermals (Peterson 1980). However, it has a wider wingspan (2.4 to 2.9 m (8 to 9.5 ft)) than the wood stork and flies with its neck indrawn; it also has short legs and a long, orange-yellow bill. The white ibis (*Eudocimus alba*) has white wings with black tips, soars and glides, and flies with an outstretched neck (National Geographic Society 1983). It is much smaller than the wood stork, and the adult facial skin, bill, and legs turn scarlet during breeding season. The whooping crane (*Grus americana)* is white with black primaries showing in flight, but it is larger than the wood stork (Stokes and Stokes 1996). It has a white feathered neck and head with a black facial mask and red crown. The jabiru (*Jabiru mycteria*) is a huge stork of Central and South America that occasionally occurs in south Texas as a straggler with flocks of wood storks (National Geographic Society 1983). It is much larger than the wood stork, having a body length of 1.3 m (4.3 ft) and a wingspan of 2.3 m (7.5 ft). It can also be distinguished from the wood stork by its larger, slightly upturned dark bill and all-white wings and tail.

Status

Legal designation

Federal. The United States breeding population of the wood stork was listed as federally endangered on February 28, 1984, pursuant to the Endangered Species Act of 1973, as amended (USFWS 1984). All populations of wood storks breeding within the United States and their offspring are protected by the listing (USFWS 1996).

State. The wood stork is on the State list of endangered species in Alabama, Florida, Georgia, North Carolina, and South Carolina (USFWS 1996).

Military installations

Table 1 represents the known status of the wood stork on military installations in the southeastern United States.

Table 1
Known Status of Wood Storks on Military Installations in the Southeastern United States

State	Installation	Status on Installation
FL	Camp Blanding	Documented onsite: occasional foraging birds (Dr. Phillip Hall, Personal Communication, 1998).
	Avon Park Air Force Range	Documented onsite; small groups foraging throughout summer (Paul Ebersbach, Personal Communication, 1998).
GA	King's Bay Naval Base	Documented onsite; foraging groups throughout the year, as many as 175-250 in flocks spring through fall (Paul Schoenfeld, Personal Communication, 1998).
	Fort Benning	Documented onsite; spring and fall migrants (Michael Barron, Personal Communication, 1998).
	Fort Gordon	Documented onsite; small foraging groups in late summer (Kenneth Boyd, Personal Communication, 1998).
	Fort Stewart	Documented onsite; foraging groups of 10-30 wood storks in summer (Tim Beaty, Personal Communication, 1998).

Distribution and numbers

Of 17 species of true storks (Ciconiidae) occurring worldwide, the wood stork is the only species breeding regularly in the United States (USFWS 1996). The current range of the wood stork extends from coastal South Carolina and east-central Georgia through Florida in the United States and from Mexico southward through Central and South America to northern Argentina (Ogden 1978). Populations in the United States are disjunct from those in Mexico and Central America. Historically, the wood stork nested from eastern Texas to South Carolina (Wayne 1910; Bent 1926; Howell 1932; Oberholser 1938; Dusi and Dusi 1968; Cone and Hall 1970; Oberholser and Kincaid 1974). However, breeding populations now occur only in Florida, Georgia, and South Carolina (USFWS 1996) (Figure 1).

Wood storks disperse after each nesting season. The postbreeding summer range formerly extended to Arkansas, Tennessee, and North Carolina (Ogden 1978; USFWS 1986). Although this range has been much reduced in recent years (Ogden 1978), dispersing storks have occasionally been reported as far north as Michigan (Southern et al. 1975) and New York (Paxton et al. 1992) and as far west as Alabama and Mississippi (USFWS 1996). However, it is now believed that storks nesting in north Florida, Georgia, and South Carolina move south during winter because the large numbers of storks in freshwater wetlands of south Florida far exceed the number of storks known to breed there (USFWS 1996). Storks occurring on the Texas and Louisiana coasts in summer are thought to have dispersed from breeding colonies in southeastern Mexico (Ogden 1978). Wood storks from Mexico occur regularly as postbreeding migrants in California and

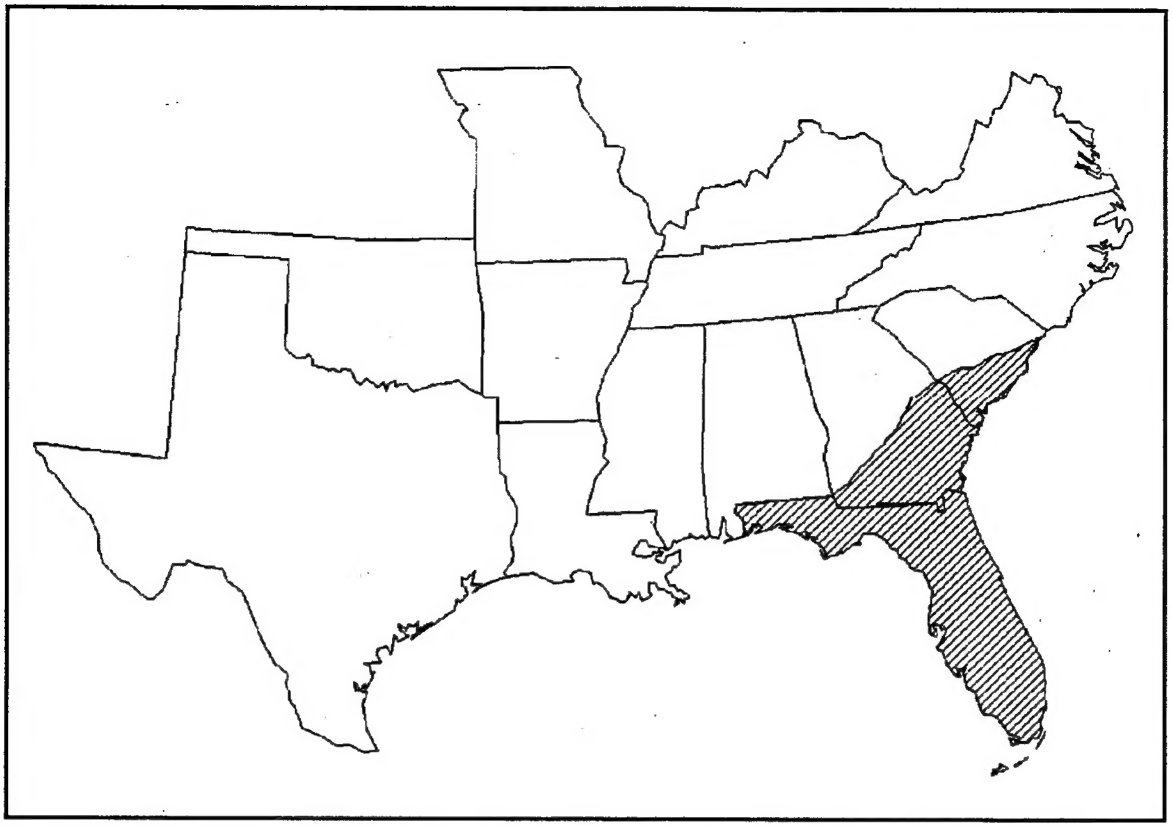

Figure 1. Approximate breeding range of the wood stork in the United States (USFWS 1996)

Arizona (Bent 1926). A small summer colony in the Imperial Valley of southeastern California (Kuhn 1998) is probably part of the Mexican population.

Since the largest population segment of the wood stork has traditionally nested in southern Florida, its decrease created the perception of instability for the entire North American population (Kushlan and Frohring 1986). Stork nesting in southern Florida has been documented for each year since 1923, but few data were collected on the number of nests or nesting pairs before the 1950s. The historic population estimate of wood storks in the United States has been based primarily on published reports that placed the southern Florida population at 30,000 to 100,000 storks in the 1930s. Allen (1958) estimated that 30,000 wood storks nested in the Corkscrew Swamp, 50,000 storks nested in what is now Everglades National Park, and other smaller colonies increased the total to 100,000 or more birds. This estimate has often been reported as the historic size for the south Florida population (Allen 1958; Sprunt and Kahl 1960; Ogden and Nesbitt 1979).

A complete search of published and unpublished records failed to find documentation that the Florida population had exceeded the 8,000 pairs reported for the northern Big Cypress and Corkscrew Swamps in 1912 (Kushlan and Frohring 1986). The highest historic estimate available for southern colonies is 3,500 pairs in 1950. Censuses in 1959 and 1960 located 10,060 nesting pairs of storks (USFWS 1986), and documentation

supported a population of 9,400 pairs in 1967 (Kushlan and Frohring 1986). The major decline occurred over the next 15 years, as the population dropped to 2,700 pairs in southern Florida, a decrease of approximately 75 percent. The wood stork recovery plan (USFWS 1986) stated that the population had stabilized between 4,000 and 6,000 pairs by the early 1980s. However, a further decline appears to have occurred, as <500 pairs were counted in the Everglades and Big Cypress regions in surveys conducted from 1987 through 1995 (USFWS 1996). During the same years, the number of nesting wood storks in Georgia increased from 4 pairs in 1965 to 1,501 pairs in 1995, and the number nesting in South Carolina increased from 11 pairs in 1981 to 821 pairs in 1995. In recent years, 30 to 40 percent of wood stork nesting has occurred in Georgia and South Carolina (Larry Bryan, Personal Communication, 1998).

Life History and Ecology

Wood storks are colonial wading birds that nest in large conspecific colonies (Bent 1926; Palmer 1962) and forage in flocks (Ogden 1978). They are highly gregarious, with as many as 25 pairs nesting in a single cypress tree (World Wildlife Federation 1990). Considerable variation exists in both intercolony and intracolony size (Rodgers et al. 1987). For example, in the early 1980s 14 colonies in north and central Florida averaged 1,760 nests per year, but the number of nests per colony ranged from 29 to 456 nests. When not nesting or foraging, storks are usually inactively perched in roosting trees or on the ground (Ogden 1978).

Behavior

Locomotion. The wood stork walks with a high-stepping, stalking gait on the ground or in shallow water (Kahl 1972). The stork takes flight from the ground after several running jumps or launches itself in one spring from an elevated perch. Although its movement appears somewhat awkward on the ground, it soars freely in the air using both flapping and gliding motions (Dusi 1971). When descending from high altitudes, it frequently exhibits an aerobatic display by diving steeply at high speeds and flipping over from side to side; air rushing through the wings produces a high-pitched whistling sound heard for considerable distances (Kahl 1972). A steep descent may also be made slowly in a parachute approach, with the wings cupped and the legs dangling vertically. After landing, especially on unstable branches, the wood stork often maintains its equilibrium by assuming the open-wing posture for prolonged periods.

Comfort movements. Kahl (1972) studied the behavior of wood storks (*Mycteria* and *Ibis* spp.) extensively and found that they perform a variety of comfort movements, as well as social displays. Typical comfort movements are individual preening of the breast and neck, mutual preening by mated pairs, head rubbing, head scratching, and stretching. Spread-wing postures, referred to as "sunning," have several functions, such as wing drying, thermoregulation, shading of nest contents, balancing, and social display (Clark 1969; Kahl 1971). Wood storks react to heat stress by panting and excreting a dilute urine onto their legs (Kahl 1963b).

Behavioral displays. Wood storks exhibit a wide variety of social, sexual, and hostile displays (Kahl 1972). Most displays at the nest function in courtship, pair formation, or defense. Courtship and sexual displays are important in establishing pair bonds, and hostile displays are generally used in nest defense. Nest displays are either primarily sexual or primarily hostile but usually contain a mixture of both elements. During social contacts away from the nest, most wood storks either ignore each other or show overt attack or escape behavior.

Initiation of nesting

The initiation of nesting is related to falling water levels and increasing concentrations of prey fish (USFWS 1986). At Corkscrew Swamp nesting is associated with the drop in water to a specific level with a high concentration of fish, as a drop without the fish does not initiate breeding activity (Kahl 1964). However, in the Everglades the rate of water level decline, rather than the critical water level, is correlated with breeding (Kushlan et al. 1975).

Nesting success requires the synchronization of breeding with wetland cycles of rainfall so that young can fledge before summer rains begin and fish disperse from feeding areas (Broward County, Florida, 1998). Successful nesting in south Florida most often occurs when colonies form from November through January and young fledge before the rainy season starts in June (Ogden 1978). In the central and northern portion of the range, colonies form from February through April and fledge young during summer months (Ogden 1978; Dusi 1986). For example, the breeding season is February through July at Kennedy Space Center on the central Florida coast (Hinkle 1998). In general, winter nesting occurs south of Lake Okeechobee while spring nesting occurs north of the lake (Kahl 1964).

Pair formation

Wood storks probably form new pair bonds at the beginning of each nesting season (Kahl 1964, 1972). In pair formation, the male storks occupy potential nest sites and unmated females approach and attempt to enter the nest sites with the males (Kahl 1972). Bachelor parties, containing a dozen or more males and as many or more females, are commonly seen at the beginning of the breeding season. Courtship behavior by storks is very important in establishing the pair bond and occurs over a period of several hours to several days (Kahl 1971, 1972). During pair formation the female gains acceptance to the nest site by performing sexual displays such as gaping and the balancing posture (Kahl 1972). The male exhibits the twig-grasping display, flying around, and display preening. Precopulatory display consists primarily of the female's bending forward with her body axis nearly horizontal and pressing up against the male's breast. In copulation the male steps onto the female's back from one side, hooks his feet over her shoulders, flaps his wings for balance, and lowers himself into copulatory position while the female holds her wings fully open in a horizontal plane. The male clatters his bill loudly and regularly while simultaneously shaking his head vigorously and beating the female's bill back and forth with his bill. The female holds her bill about 45 deg below the horizontal

and open 2 to 4 cm (0.8 to 1.6 in.) at the tip. The average duration of copulation is 14.8 seconds.

Reproduction and development

Wood storks first breed at 3 to 4 years of age (Kahl 1963a) and complete the annual reproductive cycle in 130 to 150 days (Broward County, Florida, 1998). Eggs are laid between October and June in south Florida and between February and May in central Florida (Rodgers 1990). In colonies of east-central Georgia, eggs are laid from early April through mid-May (Coulter and Bryan 1995a). The dull white eggs (Stokes and Stokes 1996) are laid 1 to 2 days apart (Broward County, Florida, 1998). Clutches usually consist of two to four eggs (Ogden 1978) with an average of approximately three eggs per nest (Girard and Taylor 1979; Coulter and Bryan 1995a). A study in which Rodgers (1990) compared historic clutch information with modern data showed that mean clutch size from 1875 through the 1980s was 3.28 (±0.74) eggs per nest.

The period of incubation lasts from 28 to 32 days (Stokes and Stokes 1996). Therefore, hatching may occur as early as November or December in south Florida and as late as June in central Florida. Coulter et al. (1984) found that hatching occurred in east-central Georgia from early May through mid-June. The chicks are altricial, weigh about 57 g (2 oz) (Broward County, Florida, 1998), and are sparsely covered with down (World Wildlife Federation 1990). Because eggs hatch in order of laying, nestlings differ in size for several weeks, and fierce competition may ensue if food is scarce (Broward County, Florida 1998). Chicks fledge in 55 to 60 days (Stokes and Stokes 1996) but return to the nest for 1 to 3 weeks to roost and be fed by the parents (Kahl 1972).

Nest behavior. Wood storks are very attentive to the nest; one or both parents remain at the nest site until the chicks are several weeks old, and then the time spent at the nest gradually diminishes until the young are independent (Clark 1979). During the first week of incubation both the male and female are frequently at the nest together, which helps to reinforce the pair bond. Sexual displays decrease rapidly as the clutch is completed and the pair bond is established; hostile displays then predominate, as these function in nest defense. It is essential for adults to remain at the nest to prevent nest takeovers and aggression (egg and nestling destruction) by unmated adult storks (Bryan and Coulter 1991).

Adults feed the 1-week-old chicks about 15 times per day (Broward County, Florida, 1998) and shade them with their bodies and outstretched wings during warm periods of the day (Rodgers et al. 1988). Although one parent may remain at the nest site for 18 to 20 hr, nest exchanges usually occur from one to four times per day (Clark 1979). During incubation and the first half of the preflight nestling stage, at least one member of the pair attends the nest site continuously while the mate, if present, stands on the nest rim or a nearby branch. During the remaining 4 weeks of the nestling stage, parental attentiveness gradually declines from about 60 percent to 0.5 percent of the day, as adults spend most of their time gathering food for the young. During the postflight stage the adults visit the nest site only to feed the chicks.

Reproductive success. Wood storks raise only one brood per nesting season (Stokes and Stokes 1996). A colony is considered successful if it fledges an average of approximately two young per nest per year (Ogden 1978). However, the fledging rate may vary considerably. For example, in colonies of north and central Florida the mean intracolony reproductive rate ranged from 0.21 to 1.54 fledglings per nest during the early 1980s (Rodgers et al. 1987). In Corkscrew Swamp Wildlife Sanctuary, Florida, production varied from 17,000 fledglings in a peak year to 0 in years of nest abandonment (Anderson 1977). Nesting attempts failed 10 times in 20 years, with 3 consecutive years of production as the maximum.

Successful nesting is closely tied to the hydrologic cycle, which determines food availability for nesting storks and their young (World Wildlife Federation 1990). Colonies often do not breed if food is scarce because of drought, whereas they may abandon eggs if rains are too heavy after the onset of breeding. In southern Florida, colonies abandoned nests after heavy rainfall (Kahl 1964). In the Everglades, desertion was associated with increases of 3 cm (1.2 in.) or more in water level within the first 2 months of nesting (Kushlan et al. 1975). Colonies formed after January were rarely successful because there was not enough time for chick development before the onset of the rainy season. Nest abandonment may also occur following periods of cold weather when adults appear to be under stress and are not exhibiting typical nest behavior (Coulter and Bryan 1995a). In dry years raccoon (*Procyon lotor*) predation can eliminate a large portion of production. Predation is related to drying of water under the colonies, which enables raccoons ready access to nests, and typically occurs late in the breeding season. Other factors affecting reproductive success include storm damage and conspecific aggression, especially by pairs that have abandoned their own nests and attempt to take over other nests.

Foraging

Wood storks are both diurnal and nocturnal feeders (Bryan 1994a). Bryan (1994a, 1995a) suggested that storks at Kathwood foraging ponds (man-made impoundments) in South Carolina foraged as much at night as they did in either crepuscular or diurnal periods. Wood storks frequently feed with other wading birds, as foraging birds are attracted to habitats where light-colored wading birds are already present (Kushlan 1977). Storks typically forage within 20 km (12.5 miles) of the colony (Bryan and Coulter 1987), but may feed as far away as 130 km (80 miles) (Ogden et al. 1978). Storks forage the greatest distances from the colony at the beginning of the nesting season, before eggs are laid, and near the end of the season when the young are large; they feed nearest the colony during incubation and nestling stages (Browder 1984).

Flight to foraging areas. Wood storks fly relatively straight lines from the nesting colony to feeding areas (Bryan et al. 1995) and utilize both flapping and soaring-gliding flight (Kahl 1964; Pennycuick 1975; Bryan and Coulter 1987). The majority of flights made to foraging sites are predominantly soaring, especially those to the more distant feeding areas (Kahl 1964; Bryan and Coulter 1987). Upon initiation of flight, the stork flaps to an altitude of several hundred feet, where rising thermal air currents are of sufficient strength to support its weight, then spirals upward with set wings to altitudes as

high as 610 m (2,000 ft) (Kahl 1964). With the occurrence of strong thermals, wood storks have been reported soaring at 1,524 m (5,000 ft) (Dusi 1971; Browder 1984). When a stork locates a thermal, others from the colony join it, and the flock soars on the thermal until reaching the feeding grounds, where they glide off singly or in formation to the site (Kahl 1964; Browder 1984). Kahl (1964) estimated that wood storks could glide up to 16 to 24 km (10 to 15 miles) when thermal updrafts were strong and high altitudes could be reached by soaring. Storks usually return to the colony before thermals wane in the late afternoon but may remain at foraging sites overnight and return on thermal currents the following morning. Seasonal analyses of flight data from a colony in east-central Georgia indicated that soaring flight was more frequent in the latter half of the breeding season when storks traveled to more distant sites (Bryan et al. 1995).

Feeding behavior. Feeding flocks may number from 75 to 100 wood storks that obtain fish and other prey items from shallow-water sources (Kahl 1964). The wood stork uses a groping technique to capture its aquatic prey (Audubon 1835; Rand 1956; Rechnitzer 1956). A feeding stork walks forward with its mandibles open 7 to 8 cm (about 3 in.) at the tip and submerged to the external nares. Upon contact with a prey item, the mandibles snap shut rapidly; the force of jaw closure and the sharp cutting edges of the bill hold captured prey securely. The head is raised, and the prey is swallowed with a quick backward jerk of the head. Kahl (1964) showed that this method of locating food is tactile and not visual; it is referred to as tactilocation and is most efficient when the density of food is high. Foot-stirring may be used in conjunction with groping to increase feeding efficiency. When underwater vegetation is abundant, a stork may stir the water by pumping the foot up and down several times and holding the bill only a few inches from the stirring foot (Rand 1956).

Diet. Wood storks feed primarily on fish (Kahl 1964; Ogden et al. 1976; Kushlan 1979b; Depkin et al. 1992; Bryan and Gariboldi 1998). Prey items usually range between 2.5 and 25 cm (1 and 10 in.) in length (Kahl 1964; Depkin et al. 1992; Bryan and Gariboldi 1998). Kushlan (1979b) found that the most common fishes consumed by storks in Everglades colonies were sunfishes (*Lepomis* spp.), marsh killifish (*Fundulus confluentus*), flagfish (*Jordanella floridae*), and Florida gar (*Lepisosteus platyrhincus*), whereas the most important prey fishes in colonies of coastal Florida were the sailfin molly (*Poecilia latipinna*), sheepshead minnow (*Cyprinodon variegatus*), and marsh killifish. Two groups of fishes composed 71 and 77 percent, respectively, of wood stork diets that comprised 8 to 10 fish species. Another study (Ogden et al. 1976) in the Everglades National Park revealed that wood stork diets consisted of 27 species of fish; 5 species of sunfish, the sailfin molly, flagfish, marsh killifish, and mosquitofish (*Gambusia affinis*) composed 90 percent of prey items. Distribution of fish species was similar to the study by Kushlan (1979b) in that the sailfin molly and sheepshead minnow contributed most to diets of storks in coastal colonies.

Nestling storks are fed the same types of food eaten by the adults (Kahl 1964). Therefore, studies of nestling regurgitation samples provide data on adult diet as well. At the Birdsville colony in east-central Georgia, studies showed that fish, primarily sunfish, were the most common components of nestling diet (Depkin et al. 1992). Sunfish,

bowfin (*Amia calva*), redfin pickerel (*Esox americanus*), and lake chubsuckers (*Erymyzon sucetta*) composed 86 percent of individual prey items and 90 percent of the biomass. Compared with wood stork diets in south Florida, prey items fed to nestlings were considerably larger in Georgia, whereas the relative density of potentially available prey was lower. In the coastal colonies of Georgia, fish from brackish/saltwater habitats dominated nestling samples, contributing from 65 to 93 percent of individual prey items and from 49 to 74 percent of prey biomass (Bryan and Gariboldi 1998). Mummichogs (*Fundulus heteroclitus*) were the most common single prey item found in coastal samples. Prey from saltwater habitats were significantly shorter and weighed less than prey from freshwater habitats. Freshwater species fed to nestlings in both inland and coastal colonies were fairly similar, containing redfin pickerel, bullhead (*Ameiurus* spp.), and sunfish. Wood stork diets also contain other prey, including amphibians, reptiles, birds, mammals, and arthropods, especially crustaceans (USFWS 1996).

Mortality

Kahl (1959) reported a wood stork that lived at least 11.7 years in the wild. A wood stork that was captured as an adult lived 30 years in captivity (Kahl 1963a). However, annual adult mortality is estimated to be approximately 20 percent and juvenile (<1 year old) mortality is approximately 40 percent (Allen et al. 1958; Ogden 1978). Egg mortality in Florida colonies is caused chiefly by avian predators, most likely fish crows (*Corvus ossifragus*) and boat-tailed grackles (*Quiscalus major*) (Girard and Taylor 1979). Nestlings are subject to mammalian predators, especially the raccoon (Rodgers et al. 1988; Coulter and Bryan 1995a). Ruckdeschel and Shoop (1987) found a relationship between predation and water level on Cumberland Island, Georgia; no depredations or nestling losses were found in trees that remained in water during the nestling period. Other mortality may be attributed to natural disasters, such as violent storms, that affect local populations. In the debris left by Hurricane Hugo, Post (1992) found eight storm-killed wood storks along a 1-km (0.6-mile) stretch of beach in Charleston County, South Carolina.

Avian Species Occurring With Wood Storks

A variety of colonial waterbirds nest in colonies with wood storks. These include the great egret (*Ardea albus*), great blue heron (*A. herodias*), anhinga (*anhinga anhinga*), snowy egret (*Egretta thula*), cattle egret (*Bubulcus ibis*), tricolored heron (*E. tricolor*), double-crested cormorant (*Phalacrocorax auritus*), little blue heron (*E. caerulea*), white ibis (*Eudocimus albus*), glossy ibis (*Plegadis falcinellus*), and black-crowned night heron (*Nycticorax nycticorax)* (Nesbitt and True 1974; Girard and Taylor 1979; Rodgers et al. 1987; Ruckdeschel and Shoop 1987; Spendelow et al. 1989).

Spendelow et al. (1989) studied patterns of co-occurrence of nesting colonial Ciconiiformes in estuarine areas of the Atlantic coast and found that the species dominating colonies in southern states are the wood stork, white ibis, tricolored heron, and cattle egret. Differences in nest placement allow a large number of species to utilize a colony. The

larger birds nest in the tops of large trees and include the wood stork, great blue heron, and great egret. The night herons, smaller egrets, and sometimes the great egret nest in smaller trees and bushes. The white ibis places nests in trees, shrubs, and occasionally low vegetation such as sawgrass (*Cladium* spp.) and bulrushes (*Scirpus* spp.) (Stokes and Stokes 1996).

Wood storks appear to be the most abundant species in the interspecific colonies that they inhabit. A heronry in Glynn County, Georgia, consisted of 100 wood storks, 20 anhingas, and 20 great egrets with about 50 active wood stork nests (Odom et al. 1979), while one in Jenkins County, Georgia, had 150 wood stork nests and about 25 great egret nests (Hopkins and Humphries 1983). Ruckdeschel and Shoop (1987) found eight species of waterbirds nesting with wood storks on Cumberland Island, Georgia. After the wood stork, the great egret and cattle egret were next in order of abundance.

Habitat Requirements

Nesting habitat

Typical wood stork nesting habitat consists of medium to large trees located in wetlands over standing water or on islands surrounded by open water (Palmer 1962; Ogden 1991; Rodgers et al. 1996). Palustrine freshwater sites are generally dominated by bald cypress (*Taxodium distichum*) (Rodgers et al. 1996). Major species associations include black gum (*Nyssa sylvatica*), red maple (*Acer rubrum*), green ash (*Fraxinus caroliniana*), sweet bay (*Magnolia virginiana*), dahoon holly (*Ilex glabra*), sweet gum (*Liquidambar styraciflua*), wax myrtle (*Myrica cerifera*), button bush (*Cephalanthus occidentalis*), and various oaks (*Quercus* spp.). Estuarine sites are usually dominated by black (*Avicennia germinans*) or white (*Laguncularia racemosa*) mangrove and may have associations of red mangrove (*Rhizophora mangle*), cabbage palm (*Sabal palmetto*), Australian pine (*Casuarina equisetifolia*), and fig (*Ficus aurea*). In colonies of north and central Florida, Rodgers et al. (1996) found that the size of nesting areas ranged from 81 m^2 (872 ft^2) to 3.07 ha (7.6 acres) with a mean area of 106 m^2 (1,140 ft^2) to 2.7 ha (6.7 acres).

Wood storks tend to use the same colony sites for many years, as long as sites remain undisturbed and surrounding wetlands provide sufficient foraging habitat (USFWS 1996). Turnover rates for colonies in South Carolina were calculated at only 0.17 with an 89 percent likelihood of remaining active in consecutive years (based on Erwin 1977). However, storks will use altered wetlands (former natural wetlands with impounded water levels) or artificial wetlands (former upland sites with impounded water) if traditional nesting sites become nonfunctional (USFWS 1996). Such habitats include impounded freshwater swamps, dredged material islands, and impoundments associated with phosphate mining operations (Rodgers et al. 1996). Ogden (1991) suggested that increases in the number of colonies in north and central Florida have been possible because of the availability of altered or artificial wetlands. Colonies in these wetlands increased from approximately 10 percent in 1960 to 60 to 82 percent between 1976 and 1986.

Nests are typically located in the upper branches of large trees, usually bald cypress, in freshwater habitats (Ogden 1978). If bald cypress is not available, nests are placed in trees of the dominant species, such as black gum (Nesbitt and True 1974), pond cypress (*Taxodium ascendens*) (Passmore 1989), or oaks (Rodgers et al. 1996). Storks may also utilize dead woody trees and smaller trees such as red maple, wax myrtle, dahoon holly, southern willow (*Salix caroliniana*), and cabbage palm. Although wood storks in north and central Florida use a variety of tree species as nesting substrate, they tend to select trees of older age and larger diameter at freshwater sites (Rodgers et al. 1996). This may be because older trees provide better support and greater stability for nests. In estuarine colonies, nests are usually located in red, white, or black mangroves (Ogden 1978; Rodgers et al. 1996) but may be in Australian pine, Brazilian pepper (*Schinus terebinthifolius*), and prickly pear (*Opuntia stricta*) (USFWS 1996).

Nest height varies with tree height. At a Georgia colony, nests were located at heights of 12 to 30 m (40 to 100 ft) above the water in cypress trees that were 20 to 30 m (65 to 100 ft) tall (Hopkins and Humphries 1983). In black gum trees of intermediate height, nest placement ranged from 2 to 10 m (6.5 to 33 ft) at Black Hammock Island in north Florida (Nesbitt and True 1974). Nests in white mangrove were only 1.7 to 4.6 m (5.6 to 15 ft) above the water on Merritt Island National Wildlife Refuge, Florida (Girard and Taylor 1979). Wood stork nests represented an intermediate nest placement among the nine species of waterbirds sharing this colony. Storks nested closer to all nearest neighbors (conspecific or other) than did any other species; the mean internest distance was 0.3 to 0.9 m (1 to 3 ft).

Wood stork nests are approximately 0.6 to 1.0 m (2 to 3 ft) in diameter (Passmore 1989) and 20 cm (13 in.) deep (Rodgers et al. 1995). The nest is loosely constructed of twigs and small limbs (Passmore 1989) and is described as a flimsy platform of sticks lined with finer materials (Stokes and Stokes 1996). After completing construction of the nest, storks add greenery to it before egg deposition (Rodgers et al. 1988). The accumulated greenery becomes coated with guano and matted down to conform to and line the inner surface of the nest. This material functions to insulate the nest contents in a porous twig structure, and new additions decrease as the nestlings mature and develop self-thermoregulation at 1 to 2 weeks of age.

Wood storks line their nests with greenery from a variety of herbaceous and woody plants found in the colony and surrounding habitat (Rodgers et al. 1988). Major plant species used in north and central Florida are bald cypress, wax myrtle, water oak (*Quercus nigra*), live oak (*Q. virginiana*), red maple, poison ivy (*Toxicodendron radicans*), and Spanish moss (*Tillandsia usneoides*). Typical marine-estuarine vegetation, such as cordgrass (*Spartina alterniflora*) and glasswort (*Salicornia virginica*) are found in coastal and island nests.

Foraging habitat

Wood storks forage in a wide variety of wetland habitats characteristic of the ecoregions in which colony sites are located (Kahl 1964; Ogden et al. 1976; Browder 1984;

Hodgson et al. 1987; Bratton and Hendricks 1988; Depkin et al. 1992; Pearson et al. 1992; Coulter and Bryan 1993; Gaines et al. 1998). Although colonies exist in South Carolina (USFWS 1986), most studies of wood stork foraging habitat have been conducted in Florida or Georgia. These studies are summarized in the following paragraphs.

Florida colonies. Ideal foraging habitat for wood storks in southern Florida consists of shallow wetlands that flood in spring and begin drying with the onset of summer (World Wildlife Federation 1990). Fish populations increase with the expanded water levels of spring and then become concentrated with the natural drawdown (dry-down), thus providing an excellent food source at the height of the nesting season (Kahl 1964; Ogden et al. 1976; Browder 1984). In the Big Cypress region southwest of Lake Okeechobee, Kahl (1964) found that storks characteristically fed in locations where fish densities were high because of concentration during the dry season. Habitats most frequently utilized were (a) freshwater marshes, characterized by sawgrass (*Cladium* spp.) or cattails (*Typha* spp.); (b) flag ponds dominated by pickerelweed (*Pontederia* spp.) and arrowhead (*Sagittaria* spp.); (c) wet prairies, covered with dense stands of grasses such as maidencane (*Panicum hemitomon*); and (d) shallow-water portions of cypress heads. In the Corkscrew Swamp of southwest Florida, storks followed the dry-down from wet prairie ponds at the higher elevations to slough ponds in the lowlands (Browder 1984). Wood storks also used man-made water sources, such as irrigation ditches and canals, especially at the beginning and end of the nesting season when few natural feeding areas were suitable for feeding.

The Everglades-mangrove region at the tip of Florida is a mosaic of low wetlands interspersed with higher hammocks and contains diverse vegetation types (Kahl 1964). Wood storks nest in colonies located in mangrove swamps along the southern coast and feed in a succession of habitats as the dry season progresses (Ogden et al. 1976). Kahl (1964) found that storks foraged primarily in brackish areas in the zone between the dense coastal mangrove forest and the freshwater Everglades. However, they begin foraging in the coastal marshes upon their arrival in November and gradually move inland to creeks, streams, and pools at the landward edge of mangrove swamps as drying occurs (Ogden et al. 1976). By the end of the nesting season, storks have extended their foraging range into the extensive inland marshes of the Everglades. Wood storks feed in habitats where prey densities are the greatest (Kahl 1964; Ogden et al. 1976). Ogden et al. (1976) found that fish densities at foraging sites in southern Florida were significantly higher than at sites where wood storks did not feed. In coastal areas mean prey density was 40 fish per m^2 (3.7 fish per ft^2) at feeding sites compared with 16.6 fish per m^2 (1.5 fish per ft^2) at nonfeeding sites. In Everglades habitats respective means were 141 fish per m^2 (13 per ft^2) and 10.3 fish per m^2 (0.9 per ft^2).

In the Lake District of north-central Florida, wood storks forage in wetlands associated with numerous permanent lakes, such as lake margins, stream and river edges, and marshes; but they also feed in small ponds and roadside ditches (Kahl 1964). Drawdown of water is less important for foraging areas because of the deeper lakes and ponds that exist throughout the year. Therefore, the seasonal change in water levels has less effect on the amount of water available for foraging in central Florida than it has on water area

in the flat terrain south of Lake Okeechobee. Wood storks also utilize man-made sites for foraging. At the Kennedy Space Center in east-central Florida, Leenhouts (1986) observed wood storks feeding at hydraulic dredging disposal areas; newly exposed dredged material contained small fishes that constitute wood stork prey.

The Water Conservation Areas, which comprise about 3,600 km^2 (1,400 square miles) of the original Everglades south and southeast of Lake Okeechobee, are heavily used by wintering wood storks, mostly nonbreeders (Bancroft et al. 1992). The Water Conservation Areas are shallow-water impoundments surrounded by levees and canals that are managed to provide flood protection and agricultural and municipal water during the dry season. The dominant vegetation consists of dense continuous stands of sawgrass (*Cladium jamaicense*) in a mosaic of other habitat types such as hardwood tree islands, pond cypress strands, and wet prairie sloughs dominated by spikerush (*Eleocharis cellulosa*) and water lily (*Nymphaea odorata*).

Georgia colonies. Wood storks in Georgia are located in both coastal and inland colonies and forage in available nearby habitats (Hodgson et al. 1987; Bratton and Hendricks 1988; Depkin et al. 1992; Pearson et al. 1992; Coulter and Bryan 1993; Gaines et al. 1998). Typical estuarine foraging habitats include tidal creeks, salt marshes, high marshes, and mud flats (Pearson et al. 1992). At Cumberland Island, Pearson et al. (1992) found 70 percent of storks feeding in salt marshes and 16 percent in palustrine habitats. Foraging was distributed relatively evenly among tidal creek, salt marsh, and mud flat. Much feeding at salt marsh sites was in small shallow sloughs that are tributaries of larger, deeper tidal creeks. Bratton and Hendricks (1988) reported that 37 percent of foraging was observed in freshwater or brackish ponds or lakes, and the remainder was in tidal marshes. At coastal colonies storks use estuarine sites chiefly during low tide and palustrine sites at high tide (Pearson et al. 1992; Gaines et al. 1998). Tidal stage is an important factor, since prey concentrates in patches of shallow water as the tide recedes to its lowest level (Gaines et al. 1998). At Cumberland Island wood storks fed almost exclusively in salt marshes at lowtide to midtide, with midtide preferred (Bratton and Hendricks 1988).

Wood storks in the inland colonies of Georgia (Birdsville in east-central and Heards Pond in south-central Georgia) are too distant from the coast to forage in brackish/saltwater habitats (Bryan and Gariboldi 1998). Although foraging areas may be 60 to 80 km (37 to 50 miles) from the colony (Ogden and Patty 1981), 85 percent are within 20 km (12.5 miles) (Coulter and Bryan 1993). Both natural and man-made freshwater habitats are utilized for inland foraging and include cypress and hardwood swamps, marshes, ponds, river drainages, submerged abandoned roads, and man-made pools (Hodgson et al. 1987; Depkin et al. 1992; Coulter and Bryan 1993). Most of these sites are covered with still or slow-moving water <50 cm (20 in.) deep and have sparse aquatic or woody vegetation (Hodgson et al. 1987; Coulter and Bryan 1993). The dominant species are pond cypress in cypress swamps, a mixture of red maple, sweet gum, and black gum in hardwood swamps, and aquatic herbaceous plants in marshes (Coulter and Bryan 1993). Coulter and Bryan (1993) found that median canopy cover in swamps was 32 percent, and Coulter (1986) found that 63 percent of all foraging sites in east-central Georgia had

a canopy cover of <20 percent. Freshwater foraging habitat had relatively low prey densities, ranging from 2.67 items per m^2 (0.25 item per ft^2) (Coulter and Bryan 1993) to 15.6 items per m^2 (1.4 items per ft^2) (Depkin et al. 1992).

Roosting habitat

Stork roosting sites are structurally similar to but more diverse than nesting sites (Ogden 1990; Bryan 1995b). Nonbreeding storks may change roost sites as they change foraging locations and will roost in trees that would be unsuitable for nesting, such as patches of trees over dry ground (Ogden 1990). If persistent foraging habitat is available in surrounding wetlands, roosts may be used for long periods of time, either seasonally or annually.

Roosting sites include cypress heads and swamps, pine or hardwood islands in marshes, mangrove islands, willow thickets or dry marshes, and the ground on levees or in open marshes (Ogden 1990; Bryan 1995b). At Cumberland Island, Georgia, wood storks roost year-round in trees at pond and lake edges (Bratton and Hendricks 1988). Roost sites receive less use in spring than during other seasons and greater use in summer and fall. Pearson et al. (1992) found that storks frequently roosted in estuary salt marshes but preferred wetlands and upland habitats. Walsh (1990) documented roost sites near Cumberland Island and found that most occurred at the upland/salt marsh interface and hosted stork groups ranging from 1 to 72 storks (mean = 12.8 storks).

In an aerial survey of roosting sites in the coastal zone of Georgia and South Carolina, Bryan (1994b) documented 110 roosts, the majority of which were in the estuarine/intertidal area rather than on the mainland or barrier islands. Two roosts were observed to have from 100 to 200 storks present during this survey. Since the survey was conducted only during daylight hours and the distance to foraging areas was only about 4 km (2.5 miles), most of these roosts were probably day roosts, i.e., sites used for roosting near feeding areas. It is likely that storks present in roosts near their foraging grounds return to primary roosts that offer more shelter at night.

Inventory and Monitoring

Wood stork nesting surveys should be conducted to coincide with the peak breeding season in the region surveyed. Surveys have been conducted in late April in south Florida, early June in north Florida (Rodgers et al. 1995), and mid-May in Georgia (Odom 1978). If more extensive surveys are feasible, Florida surveys may begin as early as late January and proceed through early July (Maffei and Jelks 1991). Data collection should be initiated with a baseline survey, and the population should be monitored annually thereafter.

The number of surveys conducted and the survey method used will depend upon the objectives of the census, available funds, and manpower. Hopkins and Humphries (1983) censused a Georgia colony of nesting wood storks at least twice a year to determine

population size and breeding success, as well as to check habitat quality. Rodgers et al. (1987) surveyed colonies in Florida every 1 to 2 weeks, counting total nests at least twice; and Ogden (1991) estimated wood stork nests from two aerial censuses per colony per year. To obtain information on reproductive success, data should be collected on clutch size and number of young fledged per nest, which requires several more visits per colony than does a survey to determine only numbers of nesting storks.

Population estimates of nesting storks have been obtained from aerial surveys (Ruckdeschel and Shoop 1987; Ogden 1991; Bancroft et al. 1988, 1992), ground counts (Girard and Taylor 1979; Odom et al. 1979; Hopkins and Humphries 1983; Rodgers et al. 1987; Bratton and Hendricks 1988), and combinations of aerial and ground surveys (Odom 1978; Kushlan 1979a; Ogden and Nesbitt 1979; Rodgers et al. 1987; Maffei and Jelks 1991; Rodgers et al. 1995). Aerial surveys with fixed-wing aircraft are relatively inexpensive, provide estimates of sites not accessible for ground counts, and can rapidly cover large areas when locating new colonies (Rodgers et al. 1995). Ogden et al. (1987) believed that aerial estimates were more accurate than ground counts in colonies where nests were scattered or access to nests from the ground was particularly difficult. Counts from fixed-wing aircraft underestimate wood storks in large colonies that contain a high proportion of other white-plumaged nesting birds (Rodgers et al. 1995). Helicopters provide slow speed and good visibility for reliable counts while causing little disturbance to nesting colonial waterbirds (Buckley and Buckley 1976; Buckley et al. 1977; Kushlan 1979a). However, helicopters are not as effective in colony location because of slow speed and are probably best suited for monitoring programs, in which reasonable but approximate census data are needed (Kushlan 1979a).

Of the three survey methods, ground counts provide the most accurate data, especially where all nests are accessible (Rodgers et al. 1995). Reproductive data, such as clutch size and number of young fledged, can be collected with ground surveys to provide information on nesting success (Girard and Taylor 1979; Rodgers et al. 1987), which is important in monitoring a sensitive species. However, ground census alone is uneconomical for large-scale programs because of the intensive use of manpower (Kushlan 1979a; Rodgers et al. 1995). Therefore, a combination of aerial surveys and ground counts may be the most effective strategy for surveying a large number of colonies (Rodgers et al. 1995). Aerial surveys can be used to locate colonies and estimate wood storks, and ground counts at selected colonies can be used to verify or expand data.

The combination of aerial and ground surveys could be especially effective on military installations, which likely have available habitat for only one or two colonies. An aerial survey would probably be unnecessary for a known colony; ground surveys could be conducted to obtain nest counts and reproductive data. If potential habitat is limited, a ground survey alone could be used to locate existing colonies and collect pertinent data.

Aerial surveys

Aerial surveys may be conducted with fixed-wing aircraft (Kushlan 1979a; Maffei and Jelks 1991; Ogden 1991; Rodgers et al. 1995) or by helicopter (Odom 1978; Kushlan

1979a; Maffei and Jelks 1991). Fixed-wing aircraft commonly used are the Cessna 172 (Bryan and Coulter 1987; Bryan 1994b; Rodgers et al. 1995), Cessna 182 (Bancroft et al. 1992; Rodgers et al. 1995), and Piper Supercub (Rodgers et al. 1987; Bryan 1994b). A Lake single-engine amphibian and a Bell 47G-2 helicopter were used to survey nests in coastal colonies of Florida (Kushlan 1979a). Observers should be trained in presurvey practice flights, and multiple flights (replicates) should be flown to reduce sampling error (Rodgers et al. 1995).

The following census procedure was used by Rodgers et al. (1995) for aerial estimates of nesting wood storks in Florida. Potential colony sites were located with maps or Global Positioning System (GPS) equipment, and a fixed-wing aircraft was used to survey the colonies. Each colony was circled several times at an altitude of approximately 100 m (330 ft), which is low enough to differentiate between nesting storks and other large waterbirds with white plumage. The number of stork nests was counted at small colonies of <50 nests, whereas the total number of stork nests was estimated at larger colonies. An inventoried nest consisted of an active nest occupied by a single stork, a pair of storks, or large stork nestlings. Nests in larger colonies were estimated by tallying subsets of 10 to 20 stork nests.

Bancroft et al. (1992) conducted aerial surveys over large areas in the Everglades by flying east-west transects spaced at 5-km (3-mile) intervals at altitudes of 240 to 300 m (800 to 1,000 ft). When an active colony was located, it was circled and a count was made of all nesting wood storks. The procedure used by Kushlan (1979a) for both fixed-wing aircraft and helicopter was to circle the colony three to five times at an altitude of approximately 120 m (400 ft) while counting nests. Both types of aircraft can be flown as low as 60 m (200 ft) without causing significant disturbance to a colony. However, helicopters should be flown slowly around the periphery of the colony and not hover over it.

Hopkins and Humphries (1983) used aerial infrared color photography in conjunction with ground surveys to count wood storks. At a scale of 25.4 mm to 305 m (1 in. to 1,000 ft), individual adult birds could be counted. However, birds standing close together or below another could not be separated, and storks could not be distinguished from great egrets. This count approximated the ground census and suggested that infrared photography might be used for monitoring nesting colonies if time and manpower present constraints.

Ground counts

Ground surveys may be conducted on foot (Odom et al. 1979; Rodgers et al. 1987, 1995) or from an airboat (Maffei and Jelks 1991; Rodgers et al. 1995). Multiple observers should be used at each colony to reduce sampling error. Rodgers et al. (1995) conducted ground counts using the following technique. Two observers moved slowly through the colony on foot or by boat along straight-line transects about 20 to 25 m (65 to 80 ft) apart or in a serpentine pattern, being careful not to miss or double-count any nest. Bright-colored flagging tape was used to mark transects at colonies with

>150 nests or those with dense understory. By using binoculars, observers could count nests far enough in advance to prevent flushing a nesting stork before the nest was counted. Only nests with storks in attendance were counted to avoid including nests of other colonial waterbirds. Since wood stork nests are larger than those of other waterbirds, they were easily visible against the green upper canopy. Survey paths extended to the edge of the colony site to ensure that all nests were included in the ground count.

To collect data on nest success in Florida colonies, Girard and Taylor (1979) tagged colonial waterbird nests, including those of storks, so observations could be made throughout the nesting season. A mirror attached to the end of a long pole allowed observations of egg and fledgling development. Nest height and internest distance could also be measured during ground counts.

Habitat Assessment

Habitat assessment for smaller avian species generally consists of sampling vegetation characteristic of preferred nesting and foraging sites to determine habitat availability and, therefore, potential use by the designated species. However, habitat for large colonial waterbirds is assessed by locating sites being used and mapping these for future reference. Wood stork habitat is usually located by conducting aerial surveys for nesting, foraging, or roosting storks. Habitat parameters can be measured by ground crews, the sites can be plotted on United States Geological Survey (USGS) topographic maps, and/or the information can be entered into a Geographic Information System (GIS) (Coulter et al. 1987b; Bancroft et al. 1992; Pearson et al. 1992; Bryan 1994b; Gaines et al. 1998).

When a nesting colony is located, wood stork nests should be counted and the colony site entered by a ground crew to measure habitat parameters. Odom et al. (1979) and Rodgers et al. (1996) used circular plots of 0.04 ha (0.1 acre) to sample vegetation and measure physical characteristics (e.g., water depth) of colony sites. The identification of major tree and shrub species and measurement of tree diameter at breast height helped to determine species dominance and classification of wetland sites using Cowardin et al. (1979). Odom et al. (1979) also measured nest height and canopy height.

Roosting sites are best located with fixed-wing aircraft (Pearson et al. 1992; Bryan 1994b). Bryan (1994b) surveyed coastal habitats of Georgia and South Carolina to document roost sites used from mid-August to early October. A Cessna 172 or Piper Supercub was flown during daylight hours at approximately 90 knots and at altitudes of approximately 2,300 to 2,600 m (700 to 800 ft). Wood storks were counted and roost sites were plotted on USGS topographic maps (1:24,000 scale). Sites were classified on the basis of importance according to the average numbers of storks per roost per survey. Habitats were also classified according to local structural features and location within the coastal zone.

Pearson et al. (1992) conducted aerial surveys in Georgia coastal areas to locate both roosting and foraging habitats. Parallel transects were flown 1.8 km (1.1 miles) apart at altitudes of 230 to 245 m (755 to 800 ft). One observer recorded locations of single wood storks and groups of storks on USGS topographic maps (1:24,000). The observer recorded only storks sighted on the passenger side of the plane and located within 450 m (1,476 ft) of the flight line. Each group of storks was classified as actively feeding or roosting or as inactive on the ground.

Bancroft et al. (1992) flew systematic aerial surveys in the Florida Everglades to locate foraging habitat. Transects were spaced at 2-km (1.2-mile) intervals, and two observers in the back seat recorded feeding birds observed on either side of the aircraft within 150-m (500-ft)-wide strips paralleling the plane's path. Browder (1984) conducted surveys in southwest Florida from mid-December through May to identify foraging areas of the Corkscrew Swamp colony and the sequence in which the sites were used during the nesting season. Searches were concentrated along vectors determined by the direction of stork flights to and from the rookery. Feeding sites and the number of wood storks seen at each site were recorded on each flight.

Foraging habitat has been located by following wood storks via aircraft from nesting and/or roosting colonies to foraging sites (Meyers 1984; Coulter 1986; Coulter et al. 1987b; Coulter and Bryan 1993; Bryan 1994b). The following survey procedure was used by Coulter and Bryan (1993) in east-central Georgia. The colony was circled, and the first stork seen flying from the colony was followed. After landing, the stork was observed for at least 5 minutes to confirm foraging activity, and the number of storks was recorded at each site. A ground crew was directed into the feeding site to document general habitat characteristics, water quality, vegetation characteristics, and density of potential prey. Water quality parameters (conductivity, dissolved oxygen concentration, pH, temperature, and turbidity) were measured at a permanent stake that marked the first spot where the followed stork fed. Vegetation characteristics were sampled at 50 points placed 0.5 m (1.6 ft) apart along two 12.5-m (41-ft) transects in two randomly chosen directions radiating from the permanent stake. The general habitat was classified according to the following categories: cypress swamp, hardwood swamp, pond, and open marsh. Bryan (1994b) also recorded the flight times and direct distances from the point of origin to foraging sites and plotted their locations on USGS topographic maps.

Satellite imagery may be used to map wood stork habitat and monitor it over a period of time (Coulter et al. 1987b, Hodgson et al. 1988). Coulter et al. (1987b) mapped wood stork habitat using satellite imagery combined with ground observations. Thematic mapping imagery, which was the primary data source, could identify areas as small as 30 by 30 m (98 by 98 ft). However, smaller sites were missed, and water depth was not always identified accurately in cypress and bottomland hardwood swamps. Therefore, ground observations were needed for a complete assessment of foraging habitat.

Hodgson et al. (1988) used remote sensing and GIS to monitor wood stork foraging habitat at the Birdsville colony in Georgia. Maps of foraging habitats were created from Landsat thematic mapping imagery, one for a "wet" year and one for a "dry" year.

Change detection, proximity to the wood stork colony, and size of foraging site analyses were performed on the maps to obtain quantitative foraging habitat statistics. On a regional basis, remotely sensed data can be used to evaluate the distribution, quantity, and change of potential foraging habitat for the wood stork.

GIS techniques can be used to map locations and acreages that remain consistent in foraging habitat suitability and to determine the total amounts and nature of land cover change. Gaines et al. (1998) obtained foraging site data by methods described by Coulter et al. (1987b), logged the locations of the foraging sites into a GPS, and/or plotted them on 1:100,000 scale USGS topographic maps. Foraging sites were digitized from the topographic maps into a GIS and made into point coverages. Additional foraging locations taken with a GPS were added to this point coverage. National Wetland Inventory 7.5-min. coverages were downloaded from the USFWS internet site and used as the base habitat data within the GIS.

Impacts and Causes of Decline

Causes of decline

Factors contributing to the decline of wood stork populations were listed and discussed in the Wood Stork Recovery Plan (USFWS 1996). These are summarized in the following paragraphs.

Loss of feeding habitat. Reduction in the food base necessary to support breeding colonies is attributed to loss of wetland habitat as well as to changes in hydroperiods (Ogden and Nesbitt 1979; Ogden and Patty 1981). Wetland drainage and hydroperiod alteration are believed to have lowered the productivity and availability of fish for the wood stork and other wading birds utilizing interior wetlands of Florida (Ogden and Nesbitt 1979; Ogden 1983).

Water level manipulation. The development of intensive water management in south Florida has affected wood stork reproductive success by altering the natural hydrologic regime necessary for breeding. This has resulted in a major reduction of areas subject to natural flooding followed by gradual drying, which provides suitable concentrations of prey fish to sustain nesting colonies. Nest abandonment frequently occurs when prey fish are not available. Kushlan et al. (1975) found that a water level increase of as little as 3 cm (1.2 in.) in the first 2 months of nesting was correlated with nest desertion in colonies of the Everglades National Park (ENP) and that re-nesting efforts were usually unsuccessful.

Blake (1980) summarized the history of water management in Florida. Early water management was intended to drain wetlands for agriculture. The drainage schemes consisted of extensive seasonal (mainly summer-fall) flooding, followed by gradual declines in water levels as the drier season (fall, winter, and spring) began. The initial modifications involved digging headwater canals to drain water quickly to the ocean. Human use

of flood-prone areas increased, thus producing additional demands for further structural flood-control measures, such as levees, gates, water storage areas, use of backpumping, and construction of additional canals. These structural modifications affected vast areas in south and central Florida and made the ENP largely dependent on release of water from the Water Conservation Areas. In drought years this can be inadequate, but unseasonably large releases of water can also cause wood stork nesting failures. The wood stork population can tolerate occasional reproductive failure caused by natural occurrences, such as prolonged drought or unseasonal heavy rainfall. However, modified hydrological regimes have caused nesting failures to become chronic rather than occasional.

Predation and/or lack of nest tree regeneration. Lowered water levels after nest initiation facilitate mammalian predation because predators, especially raccoons, can enter colonies more easily (Rodgers et al. 1988). Drainage of cypress stands will prevent wood stork nesting, but colonies that are perpetually flooded will have no cypress regeneration. Storks have formed nesting colonies in the willows of clay settling ponds on islands with phosphate mining operations. However, these colonies tend to be temporary because vegetational succession results in death of the pioneering willows, leaving shrubs and dense vines to predominate the landscape (Clewell 1981). In some settling impoundments, all vegetation dies after a few years (J. Ogden in USFWS 1996).

Human disturbance. Human disturbance may cause adults to leave nests, exposing the eggs and downy nestlings to predators, sun, and rain. However, wood storks may be less sensitive to low levels of human disturbance than other wading birds. Rodgers and Smith (1995) studied mixed-species colonies of wading birds for responses to various human disturbances. Of the 15 species examined, wood storks had the smallest mean flush distance (approximately 18 m (60 ft)) in response to a walking approach and an equally small flush distance (<20 m (66 ft)) in response to a motorboat approach. Rodgers and Smith (1995) recommended setback distances for storks at 65 m (213 ft) for any type of walking activity and 63 m (207 ft) for any type of boating activity.

Chemical pollutants. Ohlendorf et al. (1978) found that eggshells collected at Merritt Island National Wildlife Refuge in 1973 were 8.9 percent thinner ($P < 0.001$) than pre-1947 samples; decrease in eggshell thickness was more closely correlated with DDE than other organochlorines. A study by Fleming et al. (1984) suggested that reproduction in north and central Florida colonies may have been adversely affected by DDE, a DDT metabolite, which was found in higher concentrations in eggs from nests in which not all eggs hatched. Mercury, cadmium, and lead were significantly higher in chicks from Florida than in those from Costa Rica (Burger et al. 1993). Tissue samples from a road-killed stork in Florida showed mercury levels below acute toxicity but within the range of residues known to have impaired reproduction in several species of birds (Eisler 1987). Gariboldi et al. (1998) indicated that some of the prey fed to stork nestlings, typically the freshwater fish, had mercury in levels of concern for sensitive avian species.

Current impacts

Programs designed to begin the ecosystem restoration process for the ENP, such as the Minimum Water Deliveries Program of the 1970's and the Experimental Water Deliveries Program beginning in the mid-1980's, have shown no evidence of benefit to wood storks (USFWS 1996). Natural hydrological patterns have not changed sufficiently to improve habitat conditions for wood storks in the Everglades basin. Peak numbers of nesting storks in the ENP were 1,500 to 2,000 pairs during the 1960's, 500 to 1,000 pairs during the 1980's, and fewer than 250 pairs since 1989. Urban and agricultural expansion in southwestern Florida continue to adversely impact the Corkscrew Swamp and other Big Cypress Basin colonies, resulting in a continuing decline in total nesting effort by storks in that region.

Management and Protection

Species recovery

Recovery plan. The objective of the revised recovery plan (USFWS 1996) is to assure the long-term viability of the United States breeding population of the wood stork in the wild, thereby allowing removal of this population from the Federal List of Endangered and Threatened Wildlife (50 CFR 17.11 and 17.12). The original recovery criteria for delisting were based on numbers of nesting pairs. However, evaluation of data suggests that numbers of nesting pairs are not a complete indication of population stability, and productivity levels exceeding a minimum standard are necessary to ensure continued viability. Furthermore, improvement in productivity and population trends must occur in the Everglades and Big Cypress systems. Available habitat in north Florida, Georgia, and South Carolina cannot be expected to support the entire population of wood storks.

Downlisting to threatened status requires an average of 6,000 nesting pairs and annual regional productivity greater than 1.5 chicks per nest per year, calculated over 3 years (USFWS 1996). Delisting the wood stork would require an average of 10,000 nesting pairs and annual regional productivity greater than 1.5 chicks per nest per year calculated over 5 years. As a subset of the 10,000 pairs, a minimum of 2,500 successful nesting pairs must occur in the Everglades and Big Cypress systems.

Recovery actions. Tasks and actions needed to recover the wood stork are set forth in the revised recovery plan (USFWS 1996). The following are major actions:

a. Protect currently occupied nesting, foraging, and roosting habitat from further loss or degradation.

b. Restore and enhance suitable habitat throughout the mosaic of habitat types used by the wood stork.

c. Conduct the applied research necessary to accomplish recovery goals.

d. Increase public awareness.

Management procedures

Wood storks nesting in the southeastern United States represent a highly mobile population that requires a regionally integrated recovery strategy (USFWS 1996). Wetland preservation alone is not sufficient for the long-term survival and recovery of this population. Habitat must be managed to recover and maintain the dynamic wetland processes that make available the abundant food supply required by nesting storks. A prerequisite for complete recovery is restoration of the Everglades and Big Cypress systems of southern Florida.

Recovery of the wood stork involves regional management; however, active management of all colonies, whether large or small, will contribute to its recovery, and military installations should be aware of the potential for local management. A major management task is to reduce or eliminate human disturbance to wood stork colonies. The USFWS developed a set of management guidelines for wood stork nesting, foraging, and roosting habitats with recommendations for buffer zones to reduce human disturbance (Ogden 1990). These efforts have contributed greatly to the protection of stork habitat, particularly when new developments have been proposed in areas where it could be demonstrated that storks were using specific sites (USFWS 1996). In 1994 the Florida Game and Fresh Water Fish Commission developed draft guidelines for forestry practices on lands where wood storks occur. These guidelines, when approved by the USFWS, should provide management options to enhance the species and its habitat when consistent with landowners' objectives. Artificial structures and man-made impoundments have also been constructed and tested for management purposes (Coulter et al. 1987a; Robinette and Davis 1992).

Nesting habitat. The management guidelines provided by Ogden (1990) recommended establishing two major zones around nesting colonies. The primary zone is the most critical area, and the recommended guidelines are to ensure that a colony site survives. The primary zone must extend between 300 and 460 m (1,000 and 1,500 ft) in all directions from the colony boundaries when there are no visual or broad aquatic barriers and never less than 150 m (500 ft) when there are strong visual or aquatic barriers. The exact width of the primary zone can vary within the given range depending upon the amount of visual screen surrounding the colony, the amount of relatively deep, open water between the colony and the nearest human activity, and the nature of the nearest human activity. Storks forming new colonies tend to be more tolerant of existing human activity than they are of human activity initiated after colony formation.

Activities that are likely to be detrimental and should be avoided within the primary zone at any time of year include (a) lumbering or vegetation removal; (b) any activity that reduces the area, depth, or length of flooding in wetlands under and surrounding the colony; and (c) physical construction such as a building, roadway, tower, power line, or canal. Activities that will probably be detrimental only when the colony is active are (a) human entry within 90 m (300 ft) of the colony; (b) increase or irregular pattern in human activity anywhere in the primary zone; (c) increase or irregular pattern in activity by animals in the colony; and (d) any aircraft operation within 150 m (500 ft) of the colony.

The secondary zone (Ogden 1990) should begin at the outer limits of the primary zone and extend outward for 300 to 610 m (1,000 to 2,000 ft), or to a radius of 760 m (2,500 ft) of the outer edge of the colony. Restrictions in the secondary zone are needed to minimize disturbances that might impact the primary zone and to protect essential areas outside the primary zone. Stork activities within this zone include collecting nest material, roosting, loafing, and feeding. This zone is especially important to newly fledged young and may act as an effective screen between the colony and areas of intense human activity. To prevent newly fledged young and inexperienced storks from striking tall objects, high-tension power lines must be at least 1.6 km (1 mile) from active colonies, and tall transmission towers must be at least 4.8 km (3 miles) away.

Human activities in the secondary zone that may be detrimental to nesting storks include (a) alteration in hydrology that could cause changes in the primary zone; (b) substantial (>20 percent) decrease in the area of wetlands and woods of potential value to storks for roosting and feeding; and (c) an increase in human activity above the level that existed in the year when the colony first formed, especially when visual screens are lacking. Busy highways and commercial and residential buildings may be present in limited portions of the secondary zone at the time a new colony first forms. Although storks may tolerate existing levels of human activities, it is important that these activities not expand substantially.

Artificial structures can be used in existing or preexisting colony sites where natural nesting habitat is lacking and/or degraded (Robinette and Davis 1992). Production from artificial nesting structures on Harris Neck National Wildlife Refuge in coastal Georgia has been similar to that from natural sites. Structures are made from four-by-four posts, steel re-bar, coated screen, and artificial "silk" foliage.

Foraging habitat. Ogden (1990) provided guidelines for the protection and management of wood stork foraging sites. They recommended that human intrusion into feeding sites should not occur when storks are present. Human activity should be no closer than 91 m (300 ft) where solid vegetation screens exist and 230 m (750 ft) where there is no vegetation screen. Feeding sites should not be subjected to water management practices that alter traditional water levels or the normal seasonal drying patterns. Sharp rises in water levels are very disruptive to foraging storks because of their adaptations for shallow-water feeding. Man-made structures that can cause obstruction to flight should not be constructed within the foraging protection zones. Tall towers should be limited to a 4.8-km (3-mile) radius, and power lines across long stretches of open country should be no closer than 1.6 km (1 mile). Contaminants, fertilizers, or herbicides should not be introduced into wetlands that contain stork feeding sites, especially those compounds that could adversely alter the diversity and numbers of native fishes or that could change the characteristics of aquatic vegetation.

Managing diked impoundments for wood stork use has been successful in Georgia and South Carolina during recent years. Over 28,000 ha (70,000 acres) of diked marshes in South Carolina are managed primarily for waterfowl by manipulating water levels and salinity through the use of water control structures and tidal flow (USFWS 1996).

Impoundments may be used by storks whenever water levels are shallow enough (<40 cm (16 in.)), but high-density stork use most commonly occurs during periods when fish are concentrated following drawdown. Storks find impoundments within days of a drawdown, and flocks of >300 storks may be present in a single impoundment. Drawdowns for wood stork use can often be accomplished in conjunction with water level control for waterfowl. Drawdowns should be conducted during periods when other habitats are less available for wood stork foraging, such as periods following heavy rains. High fish density is critical during the postfledging period when habitat suitable for fledgling use may reduce the high rate of mortality among newly fledged chicks.

A man-made impoundment that has been successfully managed for wood storks is on the Kathwood Lake facility near Jackson, SC (Coulter et al.1987a; Manry 1992; Bryan and Coulter 1995; Coulter and Bryan 1995b). In an effort to restore the endangered wood stork, the Department of Energy modified the bottom of the drained Kathwood Lake into four impoundments to be specifically managed as stork foraging habitat (Coulter et al. 1987a). The impoundments are periodically stocked with stork prey species such as bluegill (*Lepomis macrochirus*) and catfish (*Ictalurus* spp.) fingerlings and bullfrog (*Rana catesbeiana*) tadpoles and are managed for fish reproduction in the fall, winter, and spring (Coulter and Bryan 1995b). Biologists from the University of Georgia's Savannah River Ecology Laboratory supervise the manipulation of pond depths (Manry 1992), and water levels are drawn down to appropriate depths for foraging storks in late summer (July-September) when storks frequent South Carolina. Wood storks have utilized these impoundments every year since their construction in 1986; the primary beneficiaries are immature storks, which are present in greater numbers than adult storks (Bryan and Coulter 1995).

A wood stork foraging site was developed at modified erosion control terraces on King's Bay Naval Station, GA (Paul Schoenfeld, Personal Communication, 1998). The terraces were designed with berms and located in four increments (lifts) between mean low and mean high water. The terraces are flooded at high tide but become exposed as tides recede and trap small fish and other prey behind the berms. The terraces have provided an abundant food source for wood storks and other species feeding in and around the berms.

Roosting habitat. Although roosting sites may have only temporary use, they should be given some level of protection since they are potential nesting sites (Ogden 1990). Human activities should be avoided within 150 to 460 m (500 to 1,000 ft) of roost sites during seasons of the year and times of the day when storks may be present, especially at night. The vegetation and hydrological characteristics of sites used by flocks of 25 or more storks should be actively protected.

Research Needs

Rangewide research needs include the determination of (a) postdispersal survival and ecology of juvenile storks; (b) potential impacts of contaminants; (c) foraging ecology and habitat needs of nonbreeding (overwintering) storks; and (d) impacts of human disturbance on a landscape scale (Larry Bryan, Personal Communication, 1999). Local studies can be conducted on installations with known foraging and roosting sites to collect information such as wetland type, water depth, percent and kind of plant cover, and tree height, density, and diameter at breast height. Prey availability can be determined by sampling with minnow traps to determine prey type and relative abundance. It would be helpful to identify ages of storks present and observe the interactions of wood storks and other wading birds.

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Personal Communications

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Beaty, Tim. 1998. Wildlife Biologist, DPW, Fish & Wildlife Branch, HQS 3D IN DIV (MECH) and Fort Stewart, GA 31314-4928. (912) 767-7261

Boyd, Kenneth. 1998. Wildlife Biologist, Commander, USASC&FG, ATZH-DIE, Fort Gordon, GA 30905-5040. (706) 791-2403

Bryan, Larry. 1998. Biologist, Savannah River Ecology Laboratory, Drawer E, Aiken, SC 29802. (803) 952-7451

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Ebersbach, Paul F. 1998. Natural Resources Manager, Det 1, 6 SPTG/CEV, 29 South Boulevard, Avon Park Air Force Range, FL 33825-5700. (941) 452-4119, ext. 301

Hall, Phillip, Ph.D. 1998. Environmental Specialist, Camp Blanding ENV, Route 1, Box 465, Building 3018, Starke, FL 32091-9703. (904) 533-3456

Schoenfeld, Paul. 1998. Natural Resources Manager, King's Bay Naval Base, ATTN:FE4, 1063 USS Tennessee Avenue, Kings's Bay, GA 31547-2606. (912) 673-4663.

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Wilma A. Mitchell

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U.S. Army Engineer Waterways Experiment Station
3909 Halls Ferry Road
Vicksburg, MS 39180-6199

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13. ABSTRACT *(Maximum 200 words)*

The wood stork (*Mycteria americana*) is a large colonial wading bird that breeds in a variety of wetland habitats. Its current range extends from southern South Carolina through Florida and from Mexico to northern Argentina, but populations in the United States are disjunct from those in Mexico and Central America. Storks disperse after the nesting season; the postbreeding range formerly extended to Arkansas, Tennessee, and North Carolina but has been greatly reduced in recent years. The wood stork in the United States was Federally listed as endangered in 1984; it is State listed as endangered in Alabama, Florida, Georgia, North Carolina, and South Carolina. Typical nesting habitat consists of medium to large trees located in wetlands over standing water or on islands surrounded by open water. Storks nest at natural palustrine freshwater and estuarine sites and in artificial wetlands such as impoundments and dredged material islands. They forage in wetland habitats characteristic of the ecoregions in which nesting colonies are located. Foraging flocks of wood storks have been documented on at least six military installations in the southeastern United States. This report is one of a series of Species Profiles being developed for threatened, endangered, and sensitive species inhabiting plant communities in the southeastern United States. The work is being conducted as part of the Department of Defense (DoD) Strategic Environmental Research and Development Program (SERDP). The

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report is designed to supplement information provided in plant community management reports for major United States plant communities found on military installations. Information provided on the wood stork includes status, life history and ecology, habitat requirements, impacts and causes of decline, habitat assessment techniques, inventory and monitoring, and management and protection.